

**WELCOME
TO
THE SESSION ON
Renewable Energy (RE) Integration
and
Demand Side Management**

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INTRODUCTION

- ❖ Integrating renewable energy (RE) with Demand Side Management (DSM) involves using DSM strategies to balance the intermittent nature of renewables and improve grid stability. By enabling consumers to be more flexible with their energy use through smart grid technologies, DSM can shift or reduce demand to match periods of low RE generation, helping to manage costs, reduce emissions, and maximize the integration of renewables. This is achieved through technologies like energy storage systems, smart meters, and control systems that coordinate the grid, distributed generators, and consumer loads.

How RE integration and DSM work together

- ❖ Balancing intermittency: Renewables like solar and wind are variable, which can create instability in the grid. DSM offers flexibility from the consumer side to hedge against this variability.
- ❖ Load shifting: DSM can move energy-intensive activities from peak demand hours to times when renewable generation is high, or when demand is low.
- ❖ Peak load reduction: By reducing or shifting demand during peak hours, it becomes less necessary to build new, expensive peak power plants, which often rely on fossil fuels.
- ❖ Improved grid stability: DSM helps maintain grid reliability by balancing supply and demand, which is crucial as the amount of intermittent renewables increases.
- ❖ Cost reduction: Integrating renewables with DSM can reduce overall electricity costs by minimizing the need for peak generation and leveraging cheaper renewable energy.

Key technologies and strategies

- ❖ Smart grids: Smart grids are the foundation for integration, using two-way communication to enable coordination between utilities and consumers.
- ❖ Demand response (DR): A program where consumers change their normal electricity usage in response to price signals or grid-based incentives.
- ❖ Energy storage systems (ESS): Batteries, including behind-the-meter and grid-scale systems, can store excess renewable energy for later use, helping to smooth out supply.
- ❖ Electric vehicles (EVs): EVs can be managed by DSM to either charge during off-peak hours or use their batteries to provide power back to the grid (vehicle-to-grid).
- ❖ Advanced Metering Infrastructure (AMI): Smart meters provide real-time data that allows for more sophisticated DSM programs and consumer participation

Key objectives of load management with RE integration

- ❖ With the integration of renewable energy (RE) sources, load management aims to address the variability and unpredictability of power generation from sources like solar and wind. By intelligently controlling the timing and volume of electricity demand, load management helps balance the supply from intermittent RE with grid and user needs.
- ❖ Balance supply and demand: Since renewable sources like solar and wind are dependent on weather, their output fluctuates. Load management shifts flexible demand to match the available supply, ensuring grid stability and avoiding power shortages or surpluses that can cause grid instability.
- ❖ Mitigate intermittency and uncertainty: Load management uses predictive modeling and real-time control to smooth out the inherent fluctuations of RE generation. For example, by temporarily adjusting or delaying non-essential loads, the system can compensate for a sudden drop in solar power due to cloud cover.

Key objectives of load management with RE integration

- ❖ Reduce the need for backup generation: By more effectively using the available renewable energy, load management reduces the reliance on less efficient and often "dirtier" fossil fuel-based peaking power plants that have traditionally been used to fill generation gaps.

Economic optimization

- ❖ Minimize energy costs for consumers: Load management employs strategies like Time-of-Use (TOU) tariffs to encourage consumers to shift their high-demand energy use to off-peak hours when electricity is cheaper. This also aligns with the times when RE generation might be abundant.
- ❖ Maximize return on RE investments: For consumers with their own solar panels or other RE systems, intelligent load management ensures they use as much of their self-generated power as possible. This minimizes their electricity purchases from the grid, improving the financial viability of their RE investment.
- ❖ Optimize electricity market participation: Advanced load management in smart grids allows for the coordination of demand response (DR) programs. This enables consumers to adjust their electricity use in response to market price signals, benefiting both the consumer and grid stability.

Efficient energy use and environmental goals

- ❖ Maximize the use of renewable energy: Load management schedules energy-intensive tasks, such as charging electric vehicles (EVs) or running industrial processes, to coincide with periods of high RE generation.
- ❖ Reduce carbon emissions: By prioritizing the use of clean, self-generated electricity and minimizing the need for backup fossil fuel plants, load management contributes to lower overall greenhouse gas emissions.
- ❖ Increase energy efficiency: Load management, particularly through demand-side management (DSM) techniques, promotes efficient energy use by encouraging users to manage and reduce their overall consumption.

System and asset management

- ❖ Reduce peak load demand: Load management is used for "peak shaving," a strategy that reduces overall electricity demand during peak hours. This lessens the strain on grid infrastructure, potentially delaying or avoiding costly upgrades to generation, transmission, and distribution systems.
- ❖ Enhance network reliability: By controlling specific loads, utilities can prevent overloading during peak conditions or when RE generation is low. This provides grid support and improves the overall reliability and resilience of the power network.
- ❖ Optimize energy storage: Load management works hand-in-hand with battery energy storage systems (BESS). It can charge batteries during periods of excess RE generation and discharge them during times of high demand or low RE availability.

LOAD MANAGEMENT OBJECTIVES

- Peak clipping
- Valley filling
- Load shifting
- Strategic conservation
- Strategic load growth
- Flexible load shape

Common load management options

- Staggering of working hours of large consumers
- Staggering of holidays of large consumers
- Specified energy and power quotas for major consumers
- Rostering of agricultural loads
- Curtailment of demand – service interruptions
- Direct load control (DLC)-utility has control of directly switching off customer loads
- Interruptible load control (ILC)-utility provides advance notice to customers to switch off loads
- Time of use (TOU) tariffs- price signal provided-customer decides response

Load management steps

- Analysis of load variations
- Identification of controllable loads
- Selection of control option
- Implementation strategy

LM options

- Cool storage-chilled water, ice storage-operate compressor during off peak
- Water pumping systems
- Cogeneration-operating strategy
- Evaluate process storage possibilities
- Power pooling

Demand Side Management

- Indian utilities –energy shortage and peak power shortage
- Supply focused- build new power plants
- Capital & fuel scarcity, environmental impacts, gestation period
- Need for options-DSM & LM

DSM Concept

- DSM –Cooperative action by the customer & the utility (SEB) to modify the customer load
- DSM benefits utility, consumer & society
- Energy conservation
- Fuel switching
- Peak clipping/valley filling/load shifting

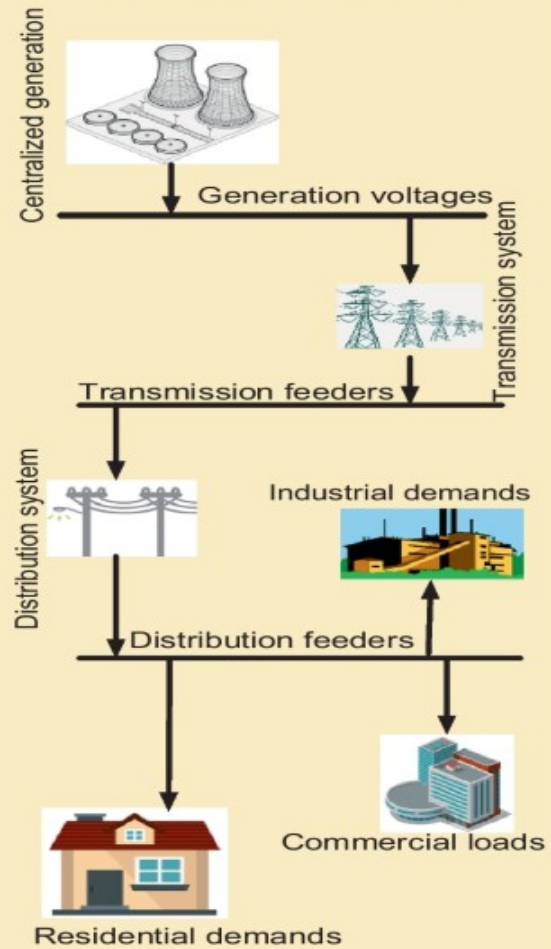
DSM Programmes

- Efficient pumping systems-Agricultural /Municipal /Industry
- Efficient motor drive systems-Industrial
- Efficient Lighting-Commercial/Residential
- Process improvements-Industrial
- Solar water heaters-Residential/Commercial
- Efficient Ac-Commercial/Residential
- Cogeneration/Captive power Industry/Commercial

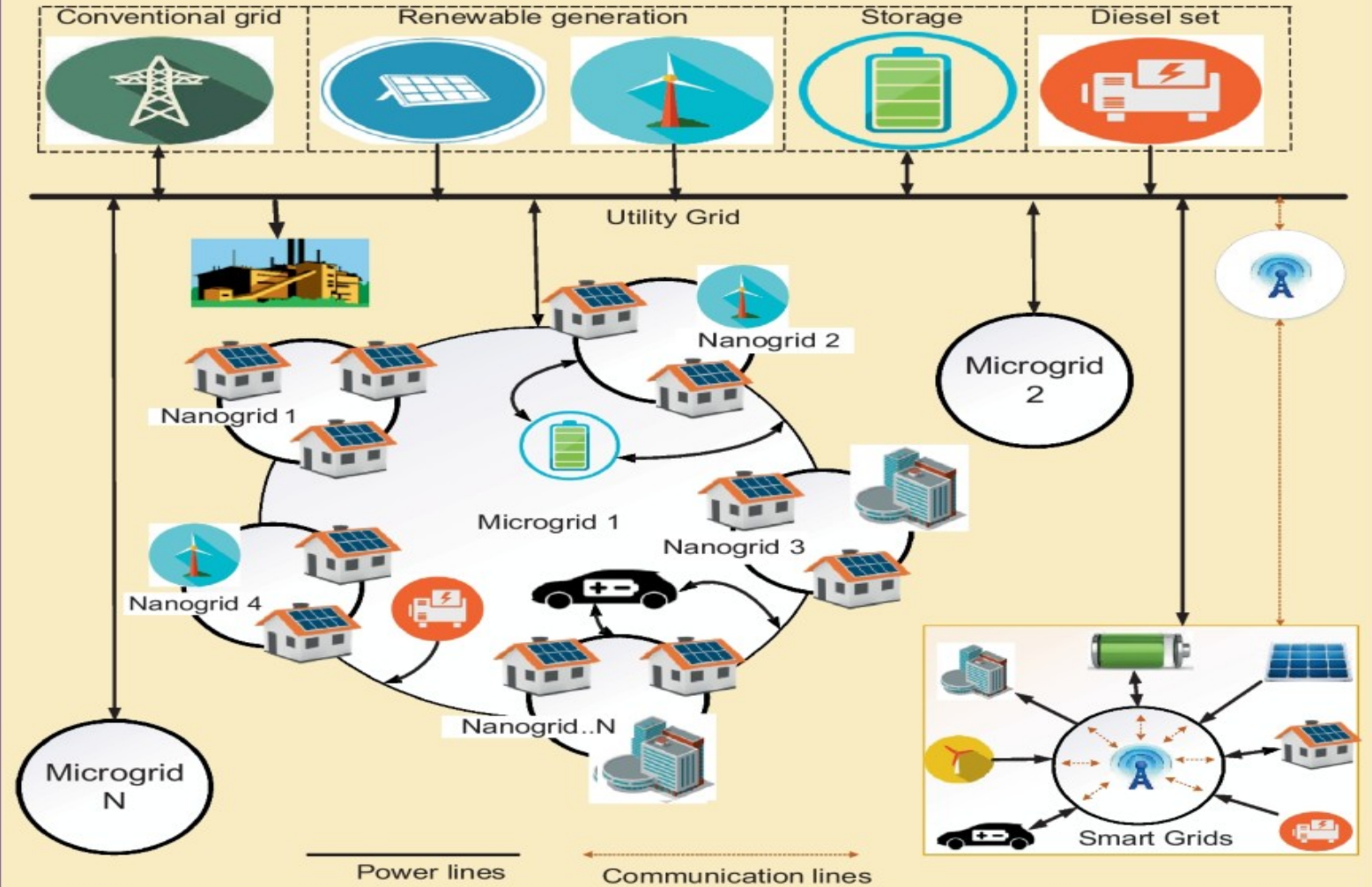
DSM Options

- Energy Efficient Motors
- Variable Speed Drives
- Waste Heat Vapor Absorption Refrigeration
- High Efficiency Fans & Pumps
- Power factor correction
- Electric arc furnace retrofit
- Efficient lighting-HPSV/CFL
- Good House Keeping
- Time of Use Tariffs

Conventional Grid



Distributed Grid



DSM versus smart grid technology

- ❖ DSM is a set of strategies and programs to manage electricity demand, while a smart grid is the underlying advanced infrastructure that enables these strategies, including those for renewable energy (RE) integration. DSM focuses on influencing consumer behavior through methods like demand response or energy efficiency, whereas the smart grid uses information and communication technology (ICT) for a two-way flow of energy and information, which allows for the sophisticated integration of DSM, RE, and other distributed resources. In essence, DSM is a component of a smart grid; a smart grid is the system that makes sophisticated DSM possible, especially in the context of intermittent renewable energy.

DSM (Demand-Side Management)

- ❖ What it is: A set of strategies and programs that manage consumer demand to reduce peak loads, save costs, and improve efficiency.

Key functions:

- ❖ Demand Response: Encouraging consumers to reduce or shift their electricity use in response to price signals or grid emergencies.
- ❖ Energy Efficiency: Implementing technologies like LED lighting to reduce overall consumption.
- ❖ Load Shifting: Moving electricity consumption from high-demand peak hours to off-peak hours.
- ❖ With RE integration: DSM can be used to match demand with renewable energy supply, for example, by scheduling high-energy use in the home when solar power is

Smart Grid Technology

- ❖ What it is: An modernized electrical grid that uses digital communication technology to detect and react to local changes in usage. It integrates ICT with traditional power systems.

Key functions:

- ❖ Two-way communication: Allows for the flow of both electricity and data between the utility and consumers.
- ❖ Advanced metering: Smart meters provide real-time data on energy usage.
- ❖ Grid management: Enables automated and real-time control and monitoring of the grid and connected distributed resources.
- ❖ With RE integration: The smart grid provides the necessary digital infrastructure to effectively integrate variable renewable energy sources like solar and wind. It balances energy supply from renewables with demand and storage, creating a more stable and reliable grid.

DSM & Smart Grid Technology

Collaboration

- ❖ A smart grid provides the technology (e.g., smart meters, two-way communication) that allows for advanced DSM strategies to be implemented and coordinated.
- ❖ Without a smart grid, DSM would be much more limited, relying on simpler, less dynamic methods.
- ❖ The smart grid's ability to handle renewable energy is enhanced by DSM. For example, the grid can use DSM to manage the load to match the fluctuating supply from a solar farm, which is made possible by the smart grid's communication and control capabilities.

DSM versus Demand Response

- ❖ DSM is the broad category of strategies to influence electricity demand, while demand response (DR) is a specific type of DSM that focuses on short-term load adjustments in response to grid events to support renewable energy (RE) integration. Think of DSM as the overarching goal of managing demand, and DR as one of the key tools within that toolbox, specifically used to balance the intermittent nature of renewables.

Difference between DSM & DR

Feature	Demand Side Management (DSM)	Demand Response (DR) with RE Integration
Definition	A portfolio of measures to influence customer electricity use to improve system efficiency and reliability.	A subset of DSM that focuses on reducing or shifting load in response to a specific event, such as high prices or low RE output.
Primary Goal	Long-term and short-term energy savings and cost reduction.	Short-term response to grid needs to match demand with variable RE supply and ensure reliability.
Time Horizon	Long-term, strategic planning (e.g., energy efficiency) and short-term adjustments.	Short-term, real-time, or near-real-time adjustments (e.g., hours, days).
Examples	Energy efficiency (e.g., LED bulbs), strategic conservation, and load shifting.	Price-based programs (e.g., <u>time-of-use rates</u>) and incentive-based programs (e.g., <u>direct load control</u>) that pay customers to reduce or shift load during critical times.
Role in RE Integration	Contributes to RE integration, but the focus is broader than just balancing supply and demand fluctuations.	Is a critical tool for RE integration, as it provides the necessary flexibility to manage the intermittency of sources like solar and wind power.

Demand response & RE integration synergy

- ❖ The synergy between demand response (DR) and renewable energy (RE) integration lies in using flexible consumer demand to match variable RE supply, which improves grid stability and efficiency. By shifting or reducing demand during peak times, DR programs help to accommodate the intermittent nature of solar and wind power, reducing costs and emissions, and allowing for greater integration of clean energy. This is achieved through real-time management that aligns electricity demand with fluctuating renewable generation.

Working

- ❖ Grid stability: When the sun isn't shining or the wind isn't blowing, DR programs can be used to shift the timing of electricity use to times when renewable energy is abundant, preventing the need for fossil fuel-based power plants to ramp up and down.
- ❖ Load balancing: Demand response helps balance the grid by acting as a flexible resource that can increase or decrease demand on short notice, which is crucial for managing the fluctuating output of renewable sources like solar and wind.
- ❖ Cost reduction: By reducing reliance on expensive peak power plants and smoothing out the supply and demand curves, the integration of DR and RE can lead to significant cost savings for both utilities and consumers.
- ❖ Enhanced RE penetration: Without flexible demand-side resources like DR, the amount of renewable energy that can be integrated into the grid is limited. DR provides the necessary

Strategies

- ❖ Incentive and price-based programs: Utilities offer financial incentives to customers for participating in DR programs, such as shifting their usage away from peak hours or reducing consumption during critical times.
- ❖ Smart grid technology: Modern smart grids are essential for implementing DR, as they allow for real-time monitoring and control of electricity usage, enabling automated responses to grid conditions.
- ❖ Bi-level optimization models: Researchers are developing advanced optimization strategies that can manage both the supply of distributed energy resources and the demand-side response in a coordinated way across the grid.
- ❖ Industry-specific solutions: Tailored DR solutions are being developed for different sectors, such as energy-intensive industries, to accommodate their unique operational requirements while still promoting the consumption of distributed RE.
- ❖ Energy storage: Battery energy storage systems, along with demand response, are essential for providing grid flexibility and for storing renewable energy for later use.
- ❖ Integrated Demand Response Programs (IDRPs): These advanced programs go beyond just electricity, coordinating DR activities across different energy

Microgrids

- ❖ Microgrids form by combining multiple energy sources and storage systems within a defined geographic area and managing them with an intelligent control system. These distributed energy resources (DERs), such as solar panels, wind turbines, generators, and batteries, are interconnected and can operate independently or in conjunction with the main power grid. A central controller manages the generation, storage, and distribution of power, allowing the microgrid to switch between "grid-connected" and "island" modes for reliability and efficiency.

Key components & roles of Microgrids

- ❖ Distributed Energy Resources (DERs): These are the sources that generate power for the microgrid.
 - Renewable sources: Solar panels, wind turbines, and fuel cells.
 - Conventional sources: Generators powered by natural gas or other fuels.
 - Combined heat and power (CHP): Systems that generate both electricity and useful heat.
- ❖ Energy Storage Systems (ESS): These capture and store energy for later use, ensuring a consistent supply.
 - Batteries: Most commonly used for storing excess energy from renewables and providing power during

Key components & roles of Microgrids

- ❖ Intelligent Control System: This is the "brain" of the microgrid, which manages all components and operations.
- Monitors real-time energy demand: The system tracks how much electricity is needed.
- Optimizes power flow: It decides which sources to use based on factors like cost, weather, and resource availability.
- ❖ Manages modes: It can seamlessly disconnect from the main grid to operate autonomously during an outage (island mode) and then reconnect when the main grid is stable.
- ❖ Controllable Loads: These are the devices and buildings

Microgrids Operation

- ❖ Planning and design: A specific geographic area (like a campus, military base, or community) is identified and its energy needs are assessed.
- ❖ Component integration: The necessary DERs and energy storage systems are chosen and installed. A control system is put in place to manage the interconnected components.
- ❖ Grid-connected mode: The microgrid can operate while still connected to the main utility grid, potentially exchanging power with it.
- ❖ Island mode: When a fault or outage occurs on the main grid, the microgrid's control system detects it and disconnects from the main grid, allowing it to continue supplying power to its local loads.
- ❖ Load balancing: The control system constantly balances the supply from the DERs with the demand from the loads.

Key roles of DSM in Microgrids

- ❖ Integrates renewable energy: DSM helps manage the instability of renewable sources by adjusting consumption based on available generation. For example, it can shift loads to times when solar or wind power is abundant.
- ❖ Optimizes energy costs: DSM programs, combined with microgrid control and storage systems, can reduce overall energy costs by minimizing peak demand and using energy more efficiently.
- ❖ Improves system reliability: By managing load and coordinating with local generation and storage, DSM helps ensure a consistent and reliable power supply, especially during grid outages when the microgrid operates independently.
- ❖ Enhances grid stability: DSM can help stabilize the microgrid by reducing the peak-to-average ratio of electricity consumption. This makes the system more resilient and efficient.
- ❖ Empowers consumers: Advanced DSM systems can use technologies like IoT and blockchain to allow consumers to participate more directly in energy management, even enabling peer-to-peer energy trading within a community microgrid, explains Frontiers

Nanogrids

- ❖ Nanogrids form by integrating a local power source (like solar panels), a load (like a home's appliances), and a controller to manage power flow. Power electronic converters are crucial for this process, as they interface the sources and loads, which can be AC or DC, and enable the nanogrid to operate either autonomously or connect to a larger grid through a gateway. The system is designed to be small-scale, often under 20kW,



Key components and roles of Nanogrids

- ❖ Local power production: This is the primary source of energy, such as solar panels or a small wind turbine.
- ❖ Load: This refers to the devices consuming the power, such as household appliances like refrigerators and lights.
- ❖ Controller: A controller manages the flow of electricity, optimizing its use from the local source and storage to the load.
- ❖ Power electronic converters: These are essential for interfacing the different components. They can convert DC power from solar panels to AC power for standard appliances, or vice-versa.
- ❖ Energy storage (optional but recommended): A battery or other storage system helps stabilize the power supply, especially when the local generation is intermittent.
- ❖ Gateway: This is a bidirectional connection that allows the nanogrid to connect to other nanogrids, microgrids, or the main utility grid.

Working of Nanogrids

- ❖ Power generation: The local source, like solar panels, generates electricity.
- ❖ Power conditioning: Power electronic converters transform the generated electricity to the correct voltage and type (AC or DC) for the loads.
- ❖ Power management: The controller decides how to distribute the power. It can send it directly to the loads or store it in the energy system for later use.
- ❖ Power delivery: The power is delivered to the loads, ensuring they have a stable supply.
- ❖ Interconnection: The gateway allows the nanogrid to share any excess power with the larger grid or draw power from it when local generation is insufficient.

Key roles of DSM in Nanogrids

- ❖ In a nanogrid, Demand Side Management (DSM) is a critical strategy that enables the grid's energy management system (EMS) to influence local consumption patterns. This coordination of consumer loads with distributed generation, energy storage, and the utility grid allows the nanogrid to operate more efficiently, reliably, and economically.

Following are the key roles:

- ❖ Optimal use of renewable energy: DSM helps nanogrids maximize the use of local renewable energy sources like solar photovoltaics (PV). By shifting loads to align with peak solar generation, the nanogrid can reduce reliance on the utility grid and prevent the curtailment of excess renewable energy.
- ❖ Grid independence and resilience: Nanogrids can use DSM to reduce overall energy demand and leverage on-site battery storage during grid outages. This increases the nanogrid's resilience, allowing it to operate autonomously for longer periods.

Key roles of DSM in Nanogrids

- ❖ Peak demand reduction: Shifting or reducing load during peak hours—when electricity prices and demand on the main grid are highest—decreases overall energy costs for the nanogrid owner. Techniques include:
 - Time-of-Use (ToU) Pricing: Charging higher prices for electricity during peak hours to encourage consumers to shift demand.
 - Direct Load Control (DLC): Allowing the utility or nanogrid operator to remotely switch off certain non-critical loads, such as air conditioners, during high-demand events.
- ❖ Enhanced grid stability: When multiple nanogrids are aggregated into a microgrid or virtual power plant (VPP), they can collectively respond to utility grid requests. By dispatching or curtailing their loads, they can help stabilize the larger grid

Key roles of DSM in Nanogrids

- ❖ Consumer cost reduction: Through load shifting, consumers can take advantage of lower electricity rates during off-peak hours. For example, programming a dishwasher to run overnight can significantly lower electricity bills.
- ❖ Economic optimization: Advanced EMS in nanogrids use algorithms to optimally schedule resources (renewables, batteries, and loads) to minimize the total cost of energy. This can involve optimizing the use of flexible loads and exploiting different utility pricing strategies, such as fixed-rate or real-time pricing.
- ❖ User preference and flexibility: Nanogrid EMS can be customized to align with user preferences and comfort levels. This means some loads can be categorized as "flexible" (e.g., washing machine), "semi-flexible" (can only accept additional load), or "non-flexible" (cannot be shifted).

DSM & Nanogrids Collaboration

- ❖ The integration of DSM in a nanogrid involves an advanced energy management system (EMS) and smart devices.
- ❖ Monitoring: Smart meters and sensors constantly monitor the home's energy consumption and generation from distributed energy resources (DERs), like solar panels.
- ❖ Forecasting: The EMS uses data inputs, such as weather forecasts and utility pricing signals, to predict renewable energy generation and household energy demand for the day ahead.
- ❖ Optimization: Using algorithms, the EMS creates an optimal operational plan to meet the forecast demand while minimizing costs and maximizing renewable energy use. This plan determines when to use stored energy, pull from the grid, or deploy DSM measures.
- ❖ Load Scheduling (DSM): The EMS signals smart appliances to automatically shift their operation to more optimal times. For example, a home's smart panel may trigger an electric vehicle to begin charging when solar production is highest and grid prices are low.
- ❖ Execution and Verification: The nanogrid carries out the planned

Electric storage systems - DSM

- ❖ Renewable energy (RE) storage systems support Demand Side Management (DSM) by managing the variable and intermittent nature of renewable sources like solar and wind power. Storage provides flexibility that allows consumers and grid operators to align electricity demand with available renewable generation, leading to a more stable, reliable, and cost-effective energy system.

Key ways RE storage systems help DSM

- ❖ Time-shifting and peak shaving -RE storage systems help shift energy usage from high-demand periods (peaks) to low-demand periods (valleys), a core function of DSM.
- ❖ Charging during off-peak hours: Storage systems, such as batteries, can be charged with cheap, abundant electricity from the grid or on-site renewables during off-peak times. Discharging during peak hours: The stored energy can then be discharged during high-demand hours, reducing the total amount of energy needed from the grid. This "peak shaving" lowers stress on the grid and can save

Integrating variable renewable energy

- ❖ The generation from solar and wind resources is highly variable and often does not align with peak demand times (e.g., solar generation peaks midday, while consumer demand peaks in the evening).
- ❖ Storing excess generation: Energy storage captures excess renewable energy generated during sunny or windy periods.
- ❖ Dispatching on demand: This stored energy can be released to meet demand when the sun is not shining or the wind is not blowing, increasing the overall share of renewable energy that can be integrated into the grid.

Enhancing grid stability and resilience

- ❖ RE storage systems provide grid support services that increase the overall reliability and resilience of the electrical network.
- ❖ Frequency regulation: Batteries can respond rapidly to grid signals, injecting or absorbing power to help stabilize grid frequency.
- ❖ Backup power: Storage systems can provide backup power to consumers during unexpected outages or grid failures. Microgrids: In local microgrids, storage systems can support isolated operation during main grid outages, ensuring a sustained power supply.

Optimizing costs for both consumers and utilities

- ❖ By enabling smarter energy usage, storage systems deliver significant financial benefits to all stakeholders.
- ❖ Lowering consumer electricity bills: Customers can reduce their electricity costs by leveraging time-of-use pricing and using their stored energy during expensive periods.
- ❖ Delaying infrastructure upgrades: By reducing peak demand, storage can postpone the need for costly upgrades to generation, transmission, and distribution infrastructure.
- ❖ New revenue streams for participants: Businesses and consumers with storage systems can participate in demand response programs and capacity markets, generating new revenue by providing grid services.

DSM through EVS

- ❖ Electric vehicles (EVs) help Demand-Side Management (DSM) by transforming from simple electricity consumers into flexible, controllable, and dispatchable energy resources for the electrical grid. Through technologies like smart charging and vehicle-to-grid (V2G), EVs can be orchestrated to shift or reduce electricity consumption during peak demand, enhance grid stability, and optimize the use of renewable energy.

Key ways EVs help DSM - Load shifting and peak shaving

- ❖ Time-of-Use (ToU) pricing: Utilities can offer different electricity rates throughout the day. By responding to these signals, smart EV chargers can automatically shift charging to off-peak hours when electricity is cheaper and demand is low. This flattens the overall grid demand curve and reduces the need for expensive "peaker" power plants that operate only during high-demand periods.
- ❖ Avoids grid overload: Uncontrolled, large-scale EV charging could overwhelm local power distribution networks and transformers. DSM

Acting as a distributed energy storage system

- ❖ Vehicle-to-Grid (V2G): With bidirectional charging capabilities, EVs can act as "batteries on wheels" to sell energy back to the grid during periods of high demand. The aggregated storage from millions of parked EVs could be used to discharge power for a short time, effectively functioning as a vast, decentralized energy reserve.
- ❖ Vehicle-to-Home (V2H) and Vehicle-to-Building (V2B): In these scenarios, the energy stored in an EV's battery can power a building during peak hours or outages. This helps a consumer reduce their reliance on the main grid during costly peak-rate periods while also providing backup power.

The effectiveness of EVs in DSM

The effectiveness of EVs in DSM depends on a few key factors:

- ❖ Communication infrastructure: A smart grid requires two-way communication between EVs, charging stations, and grid operators to enable coordinated charging and energy exchange.
- ❖ Economic incentives: Pricing schemes, rebates, and other financial rewards are needed to encourage consumer participation in DSM programs.
- ❖ Control and optimization: Intelligent software and algorithms are necessary to schedule charging, optimize energy flow, and balance the needs of EV owners with grid requirements.
- ❖ Consumer acceptance: Education and clear communication are vital to address concerns like "range anxiety" and encourage consumers to adopt new charging habits for grid optimization.

Thank You